APPENDIX J

Analysis/Modeling

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

POST CALIBRATION GROUND WATER MODELING

Following calibration, the ground water models were used to predict the impacts of projected water demands on the resource. Two sets of model simulations using identical rainfall conditions were performed for this purpose. The first set of runs represented estimated 1990 water demands, while the second represented projected 2010 water demands under the assumption that water use characteristics and management conditions in the region would remain constant. Comparisons between the two time periods, as well as the application of resource protection criteria pertaining to Surficial Aquifer System drawdowns under wetland systems and water levels in the Floridan aquifer, were used to identify potential problems.

There are inherent differences between modeling for the purpose of calibration and modeling for the purpose of prediction. In the first case, the objective is to simulate water levels for an actual period of time. Great efforts are taken to collect accurate values of rainfall and water use for that period. During the calibration process, the model is in a state of flux. Any data input to the model may be adjusted to move the model towards a more realistic representation of the ground water system, where the ground water system is described by measured values of water levels. When the accuracy of this representation meets pre-determined specifications, the model is calibrated.

Predictive modeling, such as that done for the water supply plans, begins with a previously calibrated model. The objective of the modeling is to predict the response of the ground water system to some specified stress (e.g., a 1-in-10 drought, or increase in water use). Because the stresses being simulated may never have occurred, there are no measured water levels against which to check the veracity of the model. All components of the model that do not vary with time (e.g., hydraulic properties, horizontal and vertical discretization) are fixed at the values established during calibration. The time variant variables (recharge, ET rate and water use) may be significantly different from the values applied during calibration. The issues in documenting the modeling for the water supply plan are not that the values themselves are different, but that the methods used to estimate those variables differ from those used during the calibration.

There are several areas in which the model data estimation methods used in the UEC Water Supply Plan differ from those used during the calibration of those same models.

WATER USE

Water use in the models is divided into three categories: public water supply, residential self-supply, and irrigation. The methods used to estimate each category have evolved during the course of the water supply plan. The following assumptions form the basis for demand estimates calculated for each use category.

Public Water Supply

U.S. Census data were used as basis for 1990 population. Block group level information was used as the basic unit of analysis. The population served by PWS and the self-supplied population were calculated by multiplying the number of occupied dwelling units by the average persons per occupied unit for each respective block group. The result of this calculation was subsequently assigned to specific census block groups, assuming a uniform population distribution. These population data were input as polygon coverages into the SFWMD GIS. Utility service areas and planning areas were also entered into the GIS as polygon coverages and superimposed on the census block data in order to assign population to specific utilities.

Population projections for 2010 were based on local government comprehensive plans and distributed areally using traffic analysis zones (TAZs). For those jurisdictions whose comprehensive plan did not extend population projections to 2010, the population projection was extrapolated to provide a 2010 population estimate. In addition, all demands for 2010 were taken from existing facilities or those proposed in existing permits. For example, Port St. Lucie indicated they would limit production in their surficial aquifer wellfield to 10 mgd, and any additional demand would come from the Floridan (Table J-1).

PWS includes all regional potable water supplies with existing or projected demands of 0.5 mgd or greater. PWS demands were varied monthly based on five years (or as many as available) of historical records for an individual utility. This means that if the average historical demands for the month of September are 15 percent less than those for the average month for the year, then that ratio is maintained in the modeling.

In order to address wetland protection criteria under the 1-in-10 drought condition (see the section on model post-processing for a criteria description), public water supplies were pumped at their maximum daily demand for 5 months, then pumped with a normal distribution pattern throughout the rest of the year. This pumping scenario is not a representation of expected utility demand, but reflects the difference in the anticipated drawdown resulting from continuous public water supply withdrawal compared to drawdown resulting from seasonal agricultural withdrawal.

Table J-1. Demands and Sources of Public Water Supply Utilities, 1990-2010.

Permit	Utility	Year	Demand [mgd] Finished Water	Comments
43-00041W	Indiantown	1990	0.69	Source – 100% Surficial Aquifer; 8 wells
		2010	1.08	
43-00053W	Stuart	1990	3.22	Source – 100% Surficial Aquifer; 30 wells, 10 on stand-by status
		2010	3.95	
43-00066W	Hydratech	1990	1.10	Source – 100% Surficial Aquifer; 13 wells, 3 on stand-by, 5 installed post 1990
		2010	1.83	
43-00076W	Hobe Sound	1990	2.53	Source – 100% Surficial Aquifer; 12 wells, 3 taken out of service post 1990 for high chlorides, 2 installed post 1990
		2010	4.19	
43-00089W	Martin Co. - Port Salerno	1990	2.14	Source – 100% Surficial Aquifer; 7 wells
		2010	4.37	Source – 1.78 mgd finished water transfer from Martin Co. - North (Floridan source), remaining 2.59 mgd from Surficial Aquifer; 14 wells, 1 stand-by, 7 installed post 1990
43-00102W	Martin Co. - North	1990	1.77	Source – 100% Surficial Aquifer, 10 wells
		2010	3.79 (local) + 1.78(transfer) = 5.57	Sources – Surficial Aquifer limited by permit to 57.39 mgm (1.68 mgd average) from 13 wells, 3 installed post 1990. Remaining 3.90 mgd demand from Floridan aquifer with 78% RO efficiency, yields raw Floridan demand of 4.99 mgd from 5 wells.
43-00169W	Martin Co. - Martin Downs	1990	0.55	Source – 100% Surficial Aquifer; 6 wells, 3 installed post 1990
		2010	1.17	
43-00752W	Martin Co. - Tropical Farms	1990	0.00	Source – 100% Surficial Aquifer; 14 wells, all installed post 1990
		2010	0.91	
50-00010W	Jupiter	1990	7.92 (local) + 1.50 (transfer) = 9.42	Sources – Surficial and Floridan aquifers; 38 surficial wells,10 constructed post 1990, and 3 Floridan wells, all post 1990 construction. No water transfers in 2010.
		2010	20.36 (all local)	
50-00046W	Tequesta	1990	2.46	Sources – 1.50 mgd finished water transfer from Jupiter, remaining 0.96 mgd from the Surficial Aquifer; 14 wells, 7 abandoned post 1990 for poor water quality.
		2010	3.21	Sources – Surficial (12 wells) and Floridan Aquifers (5 wells); all Floridan and 5 Surficial wells are post 1990 construction.
56-00085W	Fort Pierce	1990	9.30	Sources – Blending of Floridan and Surficial waters; 41 Surficial and 11 Floridan wells (9 post 1990 construction). The Floridan/Surficial split was based solely on well capacities, ~ 74% (10.36 mgd) Surficial and 26% (3.64 mgd) Floridan in 2010.
		2010	14.00	
56-00142W	Port St. Lucie	1990	3.66	Source – 100% Surficial; 22 wells, 1 on stand-by
		2010	12.40	Sources – 10 mgd from Surficial, 2.40 mgd (finished water) from Floridan; 75% RO efficiency yields 3.2 mgd raw Floridan demand. 37 Surficial wells and an unspecified number of Floridan wells located in the vicinity of the existing Surficial wellfield.
56-00406W	Holiday Pines	1990	0.23	Source – 100% Surficial Aquifer; 2 wells. Insufficient capacity to meet 2010 demand, assumed that additional well capacity would be added in the area of the existing wellfield.
		2010	0.63	

Permit	Utility	Year	Demand [mgd] Finished Water	Comments
Permit	Utility	Year	Demand (mgd) Finished Water	Comments
56-00552W	The Reserve	1990	0.12	Source – 100% Surficial Aquifer, 6 wells.
		2010	4.33	Sources – Treatment plant capacity = 0.59 mgd with no plans for upgrade. Remaining 3.74 mgd demand, to be purchased from St. Lucie West.
56-00614W	St. Lucie West	1990	0.10	Sources – 100% Surficial aquifer, 6 wells. Treated by membrane softening (85% efficiency) so raw water demand=0.12 mgd
		2010	6.38 (local) + 3.74 (transfer) = 10.12	Sources – Surficial wellfield limited to 4.03 mgd (raw water) = 3.42 mgd (finished water). Remaining demand (6.70 mgd finished water) from Floridan at 75% RO efficiency = 8.94 mgd raw Floridan demand.

Residential Self Supply

Within PWS service areas, self-supplied population was held constant between 1990 and 2010. For the subregional analysis, utilities were contacted to identify self-supplied areas within their service areas. Figures J-1 to J-4 show self-supplied areas in the UEC Planning Area. There was very little difference in Martin County from 1990 to 2010. In St. Lucie County, however, there were differences between 1990 and 2010, primarily in the Port St. Lucie area. It was assumed that all new development would be connected to public water supply.

Projected self-supplied population for 2010 was distributed evenly for areas outside public water supply service areas. Self-supplied population within a utility service area was given the same per capita demand as was calculated for the utility-served population. Self-supplied demand did not vary with time in the model simulations.

Demand from small package plants (< 0.5 mgd) was also included in residential self-supply category. These demands were taken from their actual point locations at the withdrawal rates reported to FDEP.

No accounting was made of domestic irrigation demands from people on public water that use individual wells for irrigation. In addition, any recharge to the aquifer from domestic irrigation or septic tanks was not accounted for.

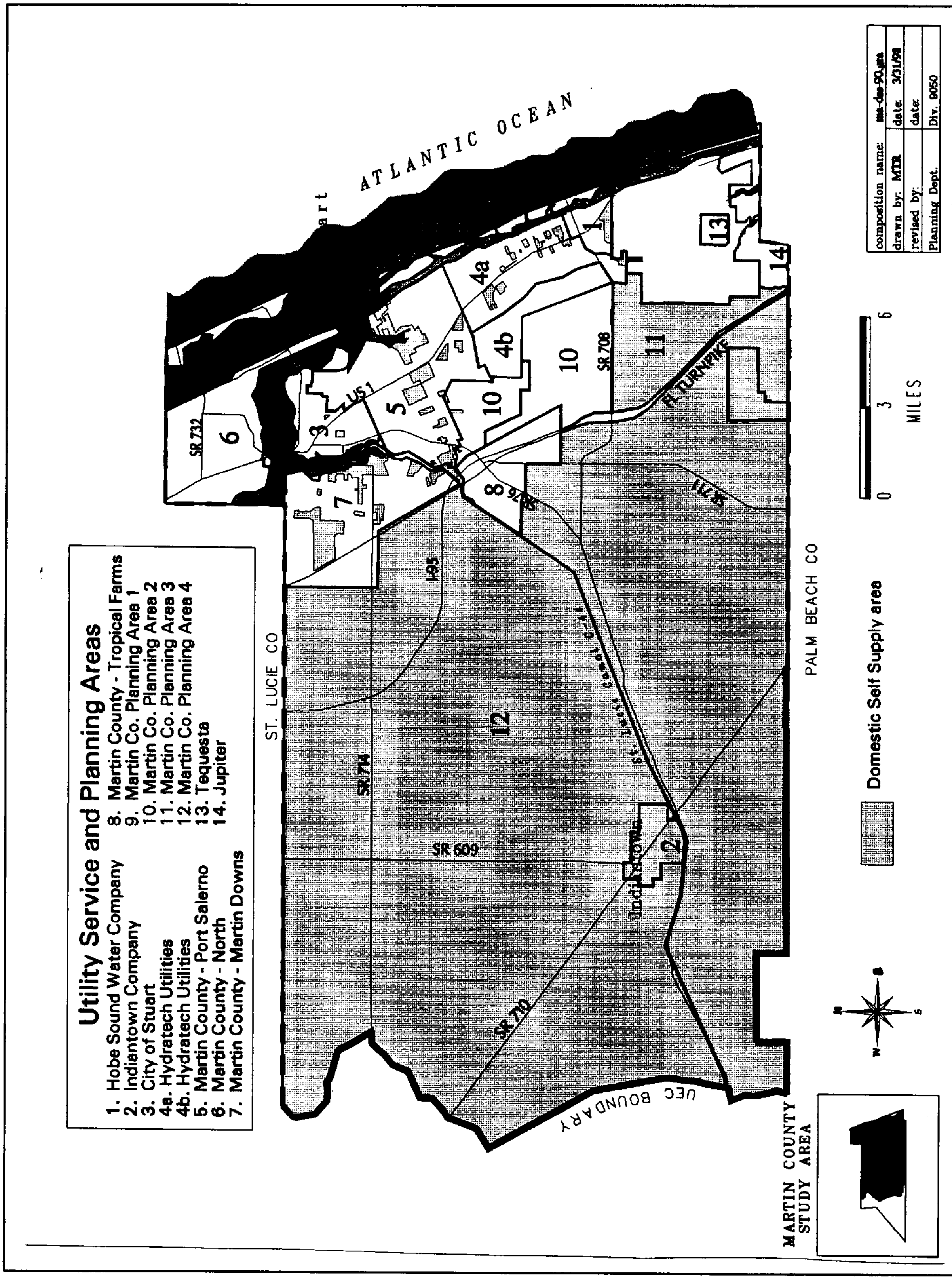

Figure J-1. Martin County 1990 Residential Self-Supplied Areas.

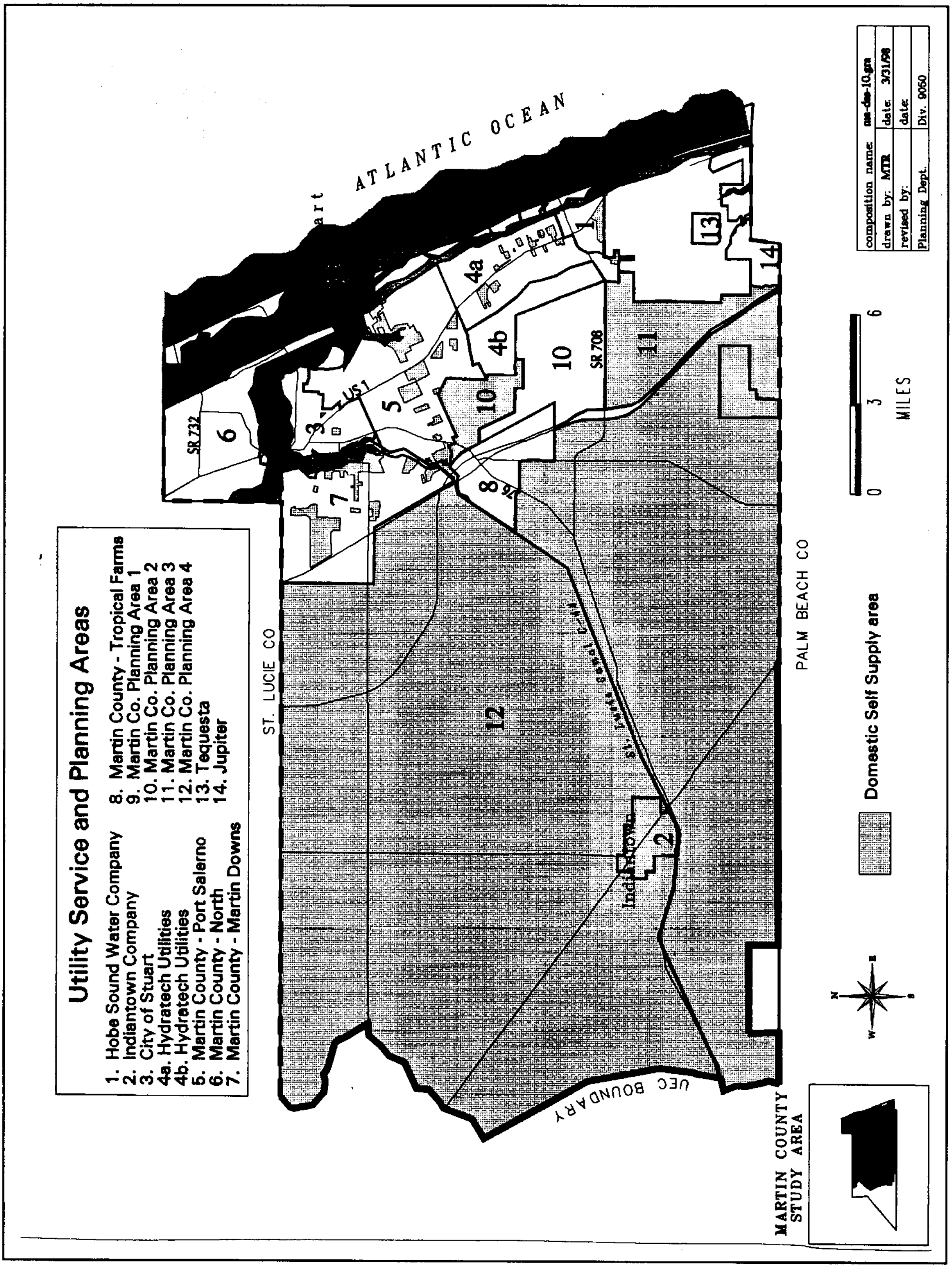

Figure J-2. Martin County 2010 Residential Self-Supplied Areas.

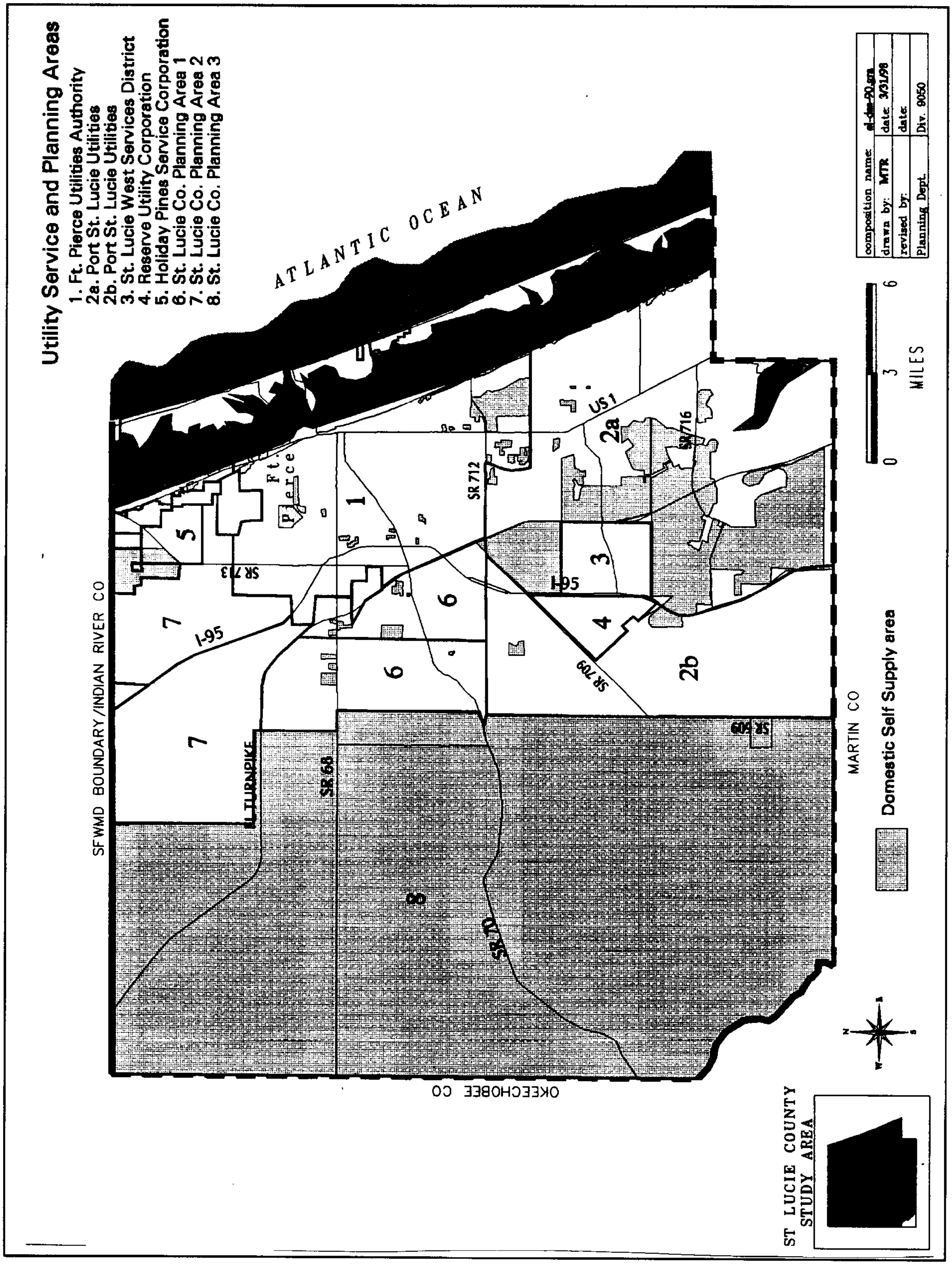

Figure J-3. St. Lucie County 1990 Residential Self-Supplied Areas.

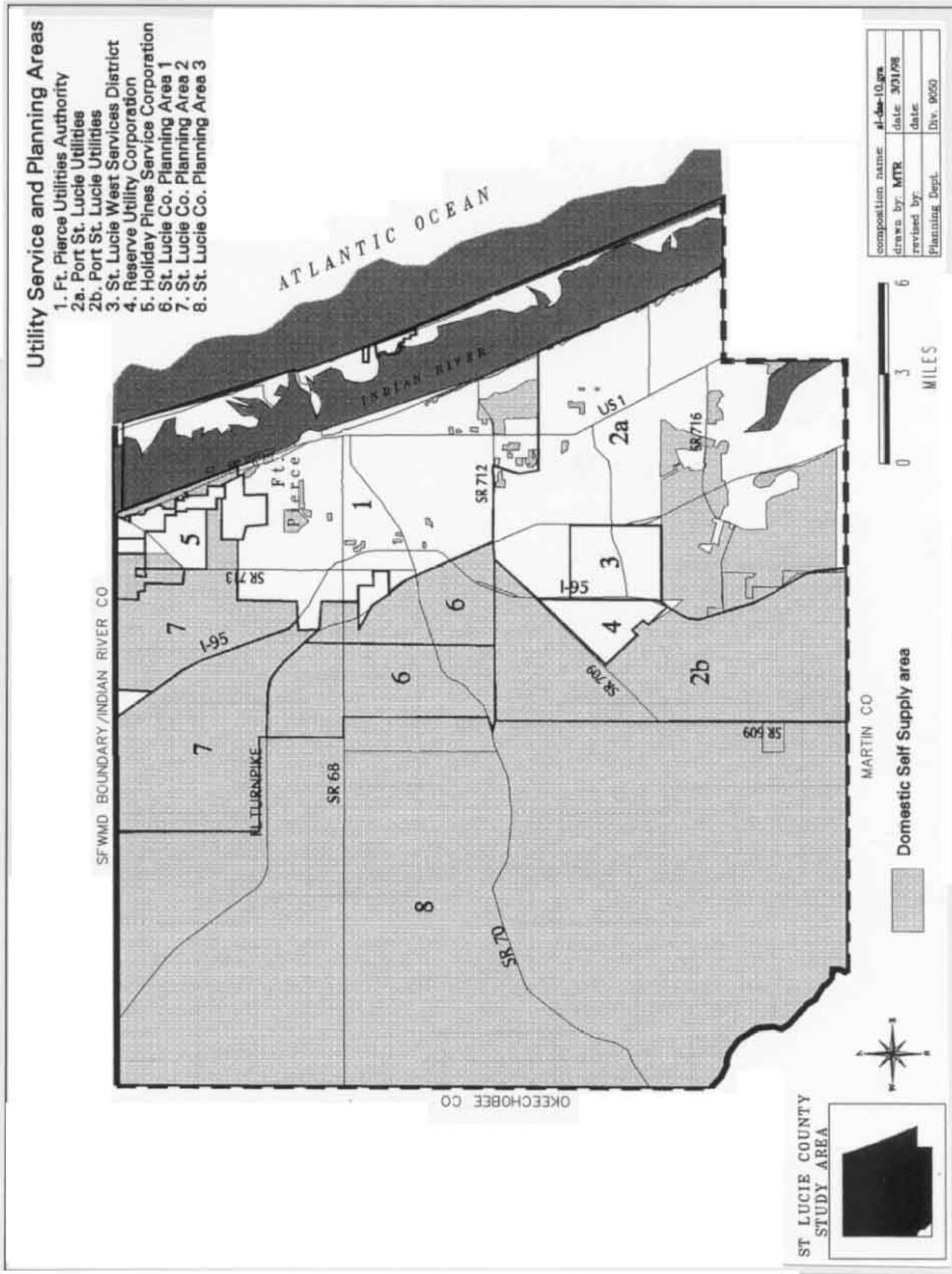

Figure J-4. St. Lucie County 2010 Residential Self-Supplied Areas.

Irrigation

This category includes any water user with an individual permit for irrigation from the SFWMD. Uses include agricultural, golf course and landscape irrigation.

Demand is calculated on a monthly basis, as the difference between evapotranspiration (ET) and effective rainfall for the rainfall event being simulated (average or 1-in-10 drought). The calculation yields demand in inches/month. Table J-2 shows the monthly irrigation demands for the seven selected rainfall stations in the UEC Planning Area.

ET and effective rainfall were estimated using a method developed by the Soil Conservation Service (SCS) and described in USDA Technical Release 21. The approach uses the modified Blaney-Criddle method to estimate ET from mean length of day and mean air temperature. It incorporates a coefficient for specific crops. An empirically derived equation is used to calculate effective rainfall as a function of total rainfall, and local soil conductivity. This method is the same one currently used in the District's regulation department. The methodology, along with all crop coefficients, is described in the SFWMD Water Use Permitting Manual, Vol. III.

The demand in inches/month is multiplied by the total irrigated area, and divided by the irrigation efficiency (both irrigated area and irrigation efficiency are taken from the permit) to get a total demand for that permit in ft^3/day.

Table J-2. Monthly Irrigation Demands (inches).

Station	Crop	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Fort Pierce	Citrus	1.57	1.56	2.96	3.34	3.2	3.47	3.35	3.33	2.02	1.36	2.05	1.61	29.82
	Veg	0.86	1.74	3.64	3.80	2.39	0.00	0.00	1.37	2.09	2.09	2.51	1.18	21.67
	Grass	1.05	1.23	3.20	4.19	4.89	4.93	4.86	4.74	3.03	1.93	2.05	1.27	37.37
Stuart	Citrus	1.60	1.67	3.25	3.65	3.59	3.00	3.25	3.63	1.76	1.49	2.24	1.58	30.71
	Veg	0.87	1.87	3.97	4.11	2.33	0.00	0.00	1.62	1.84	2.23	2.73	1.13	22.70
	Grass	1.07	1.34	3.51	4.53	4.86	4.44	4.76	5.08	2.77	2.08	2.24	1.23	37.91
Vero	Citrus	1.65	1.52	3.04	3.34	3.66	3.14	3.45	2.67	2.19	1.96	1.81	1.34	29.77
	Veg	0.98	1.70	3.71	3.77	2.43	0.00	0.00	0.80	2.26	2.70	2.26	0.94	21.55
	Grass	1.16	1.20	3.28	4.18	4.93	4.57	4.97	4.01	3.21	2.54	1.81	1.02	36.88
Cow Creek	Citrus	2.04	1.83	3.19	3.55	3.48	2.76	3.81	2.97	2.31	2.88	1.83	1.88	32.53
	Veg	1.31	2.02	3.87	3.99	2.26	0.00	0.00	1.06	2.38	3.68	2.29	1.45	24.31
	Grass	1.51	1.50	3.43	4.40	4.73	4.15	5.37	4.35	3.35	3.51	1.83	1.54	39.67
Fort Drum	Citrus	1.74	1.22	2.98	3.49	3.71	2.37	3.10	2.72	2.57	2.51	1.95	1.65	30.01
	Veg	1.07	1.40	3.65	3.93	2.47	0.00	0.00	0.84	2.65	3.28	2.40	1.24	22.93
	Grass	1.25	0.91	3.22	4.34	4.98	3.72	4.57	4.06	3.62	3.12	1.95	1.32	37.06
S 308	Citrus	1.83	1.81	3.18	3.43	3.53	3.08	2.95	3.01	1.99	2.09	2.21	1.80	30.91
	Veg	1.13	2.01	3.87	3.87	2.32	0.00	0.00	1.12	2.06	2.84	2.67	1.38	23.27
	Grass	1.32	1.49	3.42	4.27	4.77	4.48	4.38	4.38	3.00	2.68	2.21	1.47	37.87
Pratt	Citrus	2.00	1.93	3.31	3.74	3.20	2.39	3.00	2.68	1.39	1.51	2.15	1.98	29.28
	Veg	1.19	2.14	4.04	4.20	2.00	0.00	0.00	0.80	1.46	2.27	2.64	1.49	22.23
	Grass	1.41	1.58	3.57	4.64	4.42	3.75	4.45	4.03	2.38	2.10	2.15	1.60	36.08

Distribution of Floridan Use

If water demands are met from both surface and the Floridan aquifer, then distribution occurs as a two step process (described below). Use of the surficial aquifer for irrigation water supply is relatively insignificant within the planning area among growers using both surface and ground water sources. For this reason, there is little difference between the irrigation estimation methods used in the plan, and those used in the calibration of the surficial aquifer models.

This is not the case for the Floridan aquifer model. Historically, there has been a lack of information regarding Floridan water use. In some instances, the Floridan may be a permittee's sole source of irrigation water. In most cases, however, the Floridan is used in conjunction with, or as back up to, surface water resources. Consequently, the estimation of Floridan usage is not a simple process.

The first step in distributing the demands was to survey growers on their Floridan water usage. Lukasiewicz (1992) distributed a detailed questionnaire to the majority of permit holders in the study area. The questionnaire was designed to allow quantitative analysis of Floridan use during the 1989-1990 calibration year as well as "average year" patterns. The water use pattern of the respondents (36% of the recipients) was input into the model during calibration. The average pattern of the respondents was assumed for the non-respondents and also input into the model.

In preparation for the Upper East Coast Water Supply Plan, an attempt was made to fill in major gaps in the original survey. Large landholders that did not respond to the questionnaire were called individually and asked to provide information on their Floridan water-use practices.

Where no information could be acquired, the plan followed the Lukasiewicz pattern of using average values, but with an important distinction: Rather than using the average usage over the whole study area, as done in the calibration, an individual permit without information received a local average of other permits in similar circumstances. Each permit was grouped based on its physical characteristics (e.g., same basin, crop type, soil type, and irrigation methodology). Each group was assigned an average annual source water distribution and average monthly Floridan water distribution based on the responses of group members to either the questionnaire or the telephone survey.

For example:

Permit	Group id
99-00001W	Alpha
99-00058W	Alpha
99-00233W	Alpha

Group *Alpha* might represent citrus permits in the C-23 basin on Windemere soil and using flood irrigation. No Floridan utilization information is available on permit 99-00001W or 99-00233W, but 99-00058W responded to the questionnaire. If 99-00058W said that on average it used 90 percent surface water and 10 percent Floridan, and that all of its Floridan use was in the months of April and May, then that would be the initial source distribution for group alpha. This is the *initial* distribution because it leaves unanswered an important question: Is there sufficient surface water available to meet the demand?

The second step in distributing the demands was to perform a water balance. To find out if there is sufficient surface water available to meet the demand, the water balance (see Surface Water Budgets) was performed on a monthly basis for the C-23, C-24, C-25, North Fork St. Lucie River, and Tidal St. Lucie basins under average rainfall and 1-in-10 drought conditions.

The result of the calculation was a monthly balance (surplus or deficit) for each basin. If a deficit was indicated for a basin, then that amount of water had to be re-directed to other sources (primarily the Floridan aquifer) for each permit in that basin. This was the distribution of Floridan water use used in the modeling.

This process applies to the C-23, 24, 25, North St. Lucie, and Tidal St. Lucie basins. It was assumed that Lake Okeechobee would meet any needs in the C-44 basin that could not be met by runoff from rainfall within the basin.

Seventy-five percent of the irrigation “inefficiency water” is returned to the water table as recharge. For example, if a permittee is irrigating with micro-jet at 85 percent efficiency, then 15 percent of their irrigation water does not go to meeting crop demand. It was assumed that 75 percent of that 15 percent is returned to the surficial aquifer as recharge.

Surface Water Budgets to Determine Floridan Demands

A system of distributing demands across different sources was developed for the Upper East Coast Water Supply Plan. This allocation scheme was based on responses from the user survey and phone calls as well as key characteristics of the permit, such as location, crop type and irrigation method. This scheme was developed in order to estimate ground water demands to be used in conjunction with regional modeling.

Many agricultural water users in Martin and St. Lucie counties use a combination of ground and surface waters to irrigate their crops. Generally, surface water is the preferred source, and ground water, particularly Floridan aquifer water, is used when the surface water becomes inadequate to meet irrigation needs. Consequently, in order to estimate Floridan aquifer demand, knowledge of surface water availability is required.

The UEC Water Supply Plan takes the following approach to determining surface water availability:

Methodology. A volumetric water balance is performed on a monthly basis for each of the major basins under average and 1-in-10 drought conditions using the following algorithm:

Surdef = Rain + Storage + Tailret + Gwrch - Recharge - Runoff – Swdem

Surdef = Surface water surplus or deficit
Rain = Total rainfall in the basin
Storage = Water within the canal from the previous month
Tailret = Tail water return from 298 districts
Gwrch = Inflow to the canal from ground water
Recharge = Component of Rain that infiltrates the ground
Runoff = Water exiting the basin via the canal system
Swdem = Estimated surface water demand

Of the major basins, only the C-44 is omitted from this analysis. The balance approach taken assumes that water availability is solely a function of rainfall within the basin. The C-44 basin receives inflows from Lake Okeechobee that are not correlated to rainfall in the C-44 basin and therefore could not be analyzed in this manner. It is assumed that within the C-44 basin, any surface water demand that cannot be met by rainfall within the basin is supplemented by inflow from Lake Okeechobee rather than ground water. This assumption is consistent with utilization of the base model runs as the ‘status quo’ condition.

Rainfall. Average and 1-in-10 drought rainfall for each of the stations in the planning area are provided in Appendix C. The rainfall for each basin was calculated as a weighted average, where the weights were the percentage of the basin falling within the thiessen polygon for each rain station.

Storage. The surface water storage capacity for each individual basin was estimated based on widths and average cross-sections of the major canals (Table J-3).

Table J-3. Surface Water Storage Capacity.

Basin	Storage Capacity (acre-feet)	Storage Below 14' NGVD (acre-feet)
C-23	6,136	2,674
C-24	5,123	2,703
C-25	2,091	1,414
North Fork	3,191	N/A
Tidal St. Lucie	0	N/A

For C-23, C-24 and C-25 basins, only the SFWMD canals were figured into the storage capacity. Storage capacity for North Fork St. Lucie River Basin was based on 110 miles of minor canals and 15 miles of major canals within the North St. Lucie River Water Control District. Because there are no structures to maintain water level elevations, storage capacity on the Tidal St. Lucie Basin was set to zero.

These figures are rough estimates. If internal farm drainage canals and on-site retention facilities were included, it is expected the storage numbers would increase.

The storage values used in the balance equation represent the volume of water carried over within the canal from the previous month. These values range between zero and the storage capacity of the basin.

Tail Water Return Flow. Within the local 298 districts a certain amount of water recycling takes place. Where flood irrigation is used, a portion of the water that does not go to the crop root zone is returned to the main drainage system to be used by downstream neighbors. A system without tailwater recovery has an efficiency of 50 percent. Water from the same system with tailwater recovery is distributed within the range shown in Table J-4.

Table J-4. Tail Water Return Flow.

Application Efficiency (percent)	Percent to Plant Root Zone	Percent Tailwater Recovery	Percent Aquifer Recharge	Percent Lost	Total (percent)
50	50	0	37.50	12.50	100
65	50	15	26.25	8.75	100
75	50	25	18.75	6.25	100

For this analysis, the median application efficiency of 65 percent was used. This was applied to any permit within a 298 district using a flood or seepage type irrigation system.

Recharge. The recharge is the component of the total rainfall that infiltrates the ground. It was calculated for this analysis using the same methodology developed for the ground water models, where **Recharge = Rainfall - Interception loss - Runoff - Depression Storage**. It is important to note that evapotranspiration from the unsaturated zone is included in this value. A complete description of this methodology can be found in Bower *et al*., 1990.

Influx from Ground Water. The component of ground water inflow into the canals was estimated from the results of finite difference numerical models of the surficial aquifer system in Martin and St. Lucie counties. Cell-by-cell flows from the steady-state model runs were used to determine the percentage of total recharge going to rivers or drains for each basin (Table J-5).

Table J-5. Average Percentage of Recharge Flowing to Rivers and Drains.

Basin	Percent Recharge
C-23	20
C-24	16
C-25	13
North Fork St. Lucie	51
Tidal St. Lucie	20

Runoff. Volumetric basin runoff was estimated solely as a function of rainfall. The relationship between the two variables was developed by fitting a simple linear regression to the long-term rainfall and runoff records for the individual basins.

A 50-year record of continuous daily runoff from the basins contributing to the St. Lucie Estuary was required for development of the St Lucie Estuary model. The available runoff record in the C-23 and C-24 basins was relatively short, with many data gaps, and little data at all was available from the North Fork St. Lucie (NFSL) and Tidal St. Lucie (TSL) basins.

To fill in these data gaps, a program was developed to compute runoff as a function of rainfall in the C-23, C-24, NFSL, and SFSL basins on a daily basis. This program was calibrated against the actual available runoff data for C-23 and C-24 and modified for NFSL and TSL to account for variations in size and land use. The predicted runoff values were checked again using the St. Lucie Estuary model to insure that predicted flows produced conductivity levels corresponding to those measured. This data was used to estimate the monthly rainfall/runoff relationships for the aforementioned basins (Table J-6). The regression for C-25 relied on 30 years of observed rainfall in the basin and outflow recorded at the S-50 structure.

Table J-6. Monthly Rainfall/Runoff Relationships.

Basin	Equation	R^2	95% Confidence
C-23	Runoff = 1548 + 3116 (Rain)	.836	+/- 477
C-24	Runoff = -2599 + 3267 (Rain)	.842	+/- 431
NFSL	Runoff = -1805 +3807 (Rain)	.885	+/- 457
TSL	Runoff = -1046 + 1369 (Rain)	.865	+/- 194
C-25	Runoff = -2000 + 1731 (Rain)	.690	+/- 907

The equations represent the volume of monthly runoff expected from the basin for any given amount of rain. The value R^2 indicates the how well the equation accounts for observed variation in runoff. It can range from 0 to 1: the closer it is to 1, the better the model is at accounting for variation in the data. The 95 percent confidence value expresses the confidence interval for any estimate of mean runoff. In other words, you can be 95 percent confident that the mean runoff of all the months with rainfall equal a specified amount will equal the prediction plus or minus the confidence value. Runoff is in units of acre-feet, and rain is in units of inches.

Surface Water Demand. Surface water demands in the UEC basins are for agricultural irrigation. The supplemental crop requirement **Scr**, which is potential evapotranspiration **ETp** (calculated using the Blaney-Criddle method) minus the effective rainfall **Re**, was calculated for each SFWMD individual permit. The total demand was this value divided by the system irrigation efficiency, **Demand = Scr / Efficiency**.

This total demand number was apportioned to surface water, the surficial aquifer, and the Floridan aquifer according to the type of withdrawal facilities available (permit information) and user estimates (survey responses and telephone inquiries). Permits for which direct user estimates were not available were grouped according to their location and use practices, and source distributions were applied after the manner of the responding user they most resembled. The results of this analysis are located in Table J-7.

RAINFALL/RECHARGE

The 1-in-10 Drought

Model simulations were used to analyze potential impacts on wetlands and aquifer levels within the UEC Planning Area under average and 1-in-10 year drought rainfall conditions. A 1-in-10 drought condition is defined as below normal rainfall with a 90 percent probability of being exceeded over a twelve-month period. In simpler terms, this means that there is a 10 percent chance that less than this amount will be received in any given year. The 1-in-10 drought condition was codified as a preferred water supply planning goal in Chapter 373, F.S. during the 1997 legislative session.

A statistical 1-in-10 drought condition was developed for use in this analysis. This provided consistent and meaningful rainfall sets. The monthly values in these rainfall data sets have a known cumulative frequency and are derived from the historical record. The sets have the statistical property that the initial month and subsequent *cumulative* amounts (including the 12-month total) have a drought frequency of 10 percent.

The advantages of using the statistical method are that it:

- eliminates subjectivity
- minimizes influences of peaks and valleys
- eliminates inequities between rainfall stations

The statistical approach requires selection of the initial month and an analysis of 12 cumulative rainfall data sets. March was chosen as the month from which to begin the analysis because it marks the time of year when the rainfall-evapotranspiration deficit becomes the greatest. A statistical rainfall frequency analysis was performed on March rainfall for each rainfall collection station. Similar analyses were performed on historical rainfall for durations of two months (March through April) through twelve months (March through the following February). Estimates of 10 percent drought frequency rainfall were made for each duration and individual month amounts were obtained by subtraction of consecutive cumulative amounts (e.g., the November rainfall amount was obtained by subtracting the cumulative March-November drought frequency estimate from the cumulative March-October estimate).

This analysis produces a set of monthly values with a constant cumulative drought frequency of 10 percent. The individual month rainfall amounts (other than that of the initial month of March) do not have a prescribed drought frequency.

Each rainfall time series was fitted to the logarithmic-normal probability distribution. The log-normal distribution is useful in defining many random hydrologic variables where the values of the variate are the result of underlying multiplicative factors, and are known to be strictly positive (Ang, 1975), and has been previously used to define rainfall. A non-parametric test was performed on each of the time series to assess the goodness of fit to the assumed underlying probability distribution. Distributions that did not meet the goodness of fit test were discarded.

Recharge

The surficial aquifer models in the Upper East Coast region utilize a standard SFWMD methodology for estimating aquifer recharge from rainfall. During the calibration of the Martin County regional and Martin Coastal subregional models, an additional modification was made to the standard method. In both instances, a multiplier array was applied to reduce the recharge along the Atlantic coastal ridge, in order to improve the calibration of the models) was applied to all planning runs.

RESOURCE PROTECTION CRITERIA

Wetland Protection

For the Surficial Aquifer System, the resulting ground water levels from the 1990 and 2010 model runs were compared to the results from model runs without the demands to determine drawdowns resulting from water withdrawals. This difference between the modeling results with and without demands was evaluated against the wetland resource protection, which states: *ground water level drawdowns induced by pumping withdrawals in areas that are classified as a wetland should not exceed 1 foot at the edge of the wetland for more than 1 month during a 12-month drought condition that occurs as frequently as once every 10 years*. Areas where the difference exceeded the wetland resource protection criterion were identified as a potential problem area.

The Regulation Department of the SFWMD currently utilizes the following guideline for protecting wetlands from the impact of ground water withdrawals: *ground water level drawdowns induced by pumping withdrawals in areas that are classified as a wetland should not exceed 1 foot at the end of 90 days with no recharge; where public water supplies pump at their maximum daily rate, and irrigators pump at their maximum monthly rate for the full 90 day period.* The intent of the water supply plan criterion was to replicate the effect of the regulatory guideline, but for an annual 1-in-10 drought event. Modeling tests have the shown that, with the pumping scheme described in the public water supply section, the effects of the two criteria to be very similar.

Floridan Aquifer Protection

For the Floridan aquifer system, the resulting ground water levels from the 1990 and 2010 model runs were evaluated relative to the land surface elevation and the Floridan aquifer resource protection criterion. The Floridan aquifer resource protection criterion states that *ground water drawdowns induced by water use withdrawals should not cause water levels in the Floridan aquifer to fall below land surface any time during a 12-month drought condition that occurs as frequently as once every 10 years*. Areas where water levels dropped below land surface were identified as a potential problem area.

The land surface elevation used in this analysis refers to the mean elevation in each mile squared model grid cell. The elevation surface was determined using Topogrid, a surface generator available through the geographic information system software ARC/INFO. Topogrid interpolates a hydrologically correct approximation of surface elevation. The interpolated surface was created from U.S. Geological Survey (USGS) point elevation data. The elevations at these points were determined through field surveys or stereoscopic work.

Saltwater Intrusion Protection

This issue was addressed differently, in that no specific criteria was used to identify saltwater intrusion problem areas. Instead, the entire coastline was ranked according to its vulnerability to saltwater intrusion. A vulnerability mapping scheme was created to address potential saltwater intrusion concerns in the UEC coastal areas. Vulnerability mapping is a procedure that assigns numbers to each model grid cell based on weighting inputs. The grid cells with the highest numbers are the most vulnerable to salt water intrusion. Vulnerability mapping is a tool that highlights areas that have a higher relative risk of saltwater intrusion. It does not specifically indicate cells that will or will not be effected by saltwater intrusion; it is not a computer modeling effort.

The UEC vulnerability mapping scheme considered three factors. The first factor was the April water levels produced by the St. Lucie and Martin surficial aquifer regional models. These models use hydrogeologic data and system stresses to produce a water level for every model cell. The lower the water level in a cell, the greater the potential for coastal saltwater intrusion into the cell.

The second factor considered for the mapping scheme, was the Euclidean distance between a model cell and a saltwater body. The closer a cell was to a saltwater body, the greater the potential for saltwater intrusion. Values were assigned to each model cell based on the Euclidean distance.

The last factor considered was historic chloride concentration. Field measurements of chloride concentration, taken in 1994 and 1995 at PWS facilities as part of their permit requirements, were used for this purpose. Grid cells containing wells in which chloride readings exceeded 100 mg/l, or showed an overall increasing trend, were used as input into the mapping scheme. In addition, the flow from these cells was tracked for a distance of four cells, and these additional cells were also used as input. The more times a flow path crossed through a cell, the higher its vulnerability to saltwater contamination. Values were assigned to each cell that contained historic chloride data or were cross by a flow path.

A weight from 0.25 to 0.50 was applied to each factor. The factors were then multiplied by the weight that was assigned to each cell. For this effort, water levels were considered twice as important as distance from a saltwater body or previous chloride readings. The total vulnerability for a cell is the sum of the weighted values of the three factors.